4 Worry-Free Wiring Repairs

Focus on accurate wiring when replacing faulty outlets, switches, and fixtures

BY BRIAN WALO

When I tell people that I'm an electrician, they always say the same thing: "I'll do anything but electrical work." It's true that working with electricity can be dangerous, but so can working with power tools or even a kitchen knife. The keys to being safe are following a few basic rules and knowing something about the fundamentals of electricity. Whether you're replacing a broken switch or outlet or updating a fixture, the procedure is basically the same—provided you can follow a few simple rules and pay attention to detail.

It also helps to know a little about electricity itself. The fundamental electrical concept that guides my work is that of the circuit. At its most basic level, electricity flows in a circle. A battery is a good example. Batteries have a positive and a negative terminal—an "in" and an "out" if it's easier to think of it that way. Looping a wire from one terminal through a lightbulb and back to the other terminal completes the circle and lights the bulb. Transfer that idea of a circular path to your home wiring, and you'll have a much easier time making sense of any repairs you need to make.

Home electricity at a glance

The conductor (wire) that supplies power to a switch, socket, or lamp is called the "hot" or "in" side of the power supply. It's typically a black or red wire and is a constant power source coming from the electrical panel to outlets, switches, and lights.

WORK SAFELY WITH ELECTRICITY

Follow these steps, in order, to minimize the risk of shock or electrocution.

1. Identify the problem and the solution.

2. Identify the circuit(s) you need to work on, and determine the means for disconnecting the circuit (breaker or fuse). If the circuits are not identified in the panel, you'll have to do some testing to find out which breaker or fuse controls which circuit (see "Tips," p. 67). Even if they seem well labeled, it's still prudent to do some testing to verify.

3. De-energize the circuit(s) by turning off the breaker or pulling the fuse.

4. Verify the correct circuit has been shut off by checking the wiring and fixtures on that circuit with an electrical tester. (See "Make Sure the Power Is Off," *FHB* #196 or Fine Homebuilding.com.)

5. Lock out the panel to prevent anyone from energizing the circuit while you're working. You can simply tape the panel door shut and mark it with a warning. Visit FineHomebuilding.com/extras for a video demonstration.

6. Complete your work on the circuit.

7. Double-check to make sure the wiring is properly secured to the device (switch, socket, or fixture) you're working on, and the ground wires are properly attached.

8. Replace any cover plates removed during the work.

9. Re-energize the circuit and confirm operation.

Top photo and photos facing page: Michael Litchfield. Drawings Trevor Johnston.

REPLACE AN OUTLET

Outlets (aka receptacles or sockets) are easily the most abused portion of a home's electrical system—constantly pushed, pulled, wiggled, and jiggled. If you suspect an outlet is bad, plug in a lamp and wiggle the plug around a little. If the light flickers, you've found the problem. After you've turned off the power and unscrewed the faulty outlet from the box, you're likely to see one of three configurations, depending on whether the outlet is in the middle or at the end of a circuit, and whether it's wired so that power runs both through and past it (using pigtails; drawing left) or just through it (drawing center).

HOW-TO

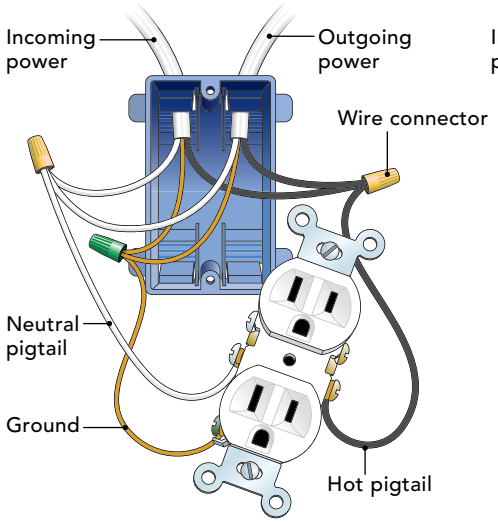
1. **Plug in a lamp** or use a tester to identify the proper circuit. (You might use nearby switches to determine if it's a switched outlet; see below.) Turn off the power, and check to be sure using a testing device.

2. **Unscrew the outlet** and pull it out of the box. If you haven't already determined whether the outlet is switched, check the side tabs now (see below).

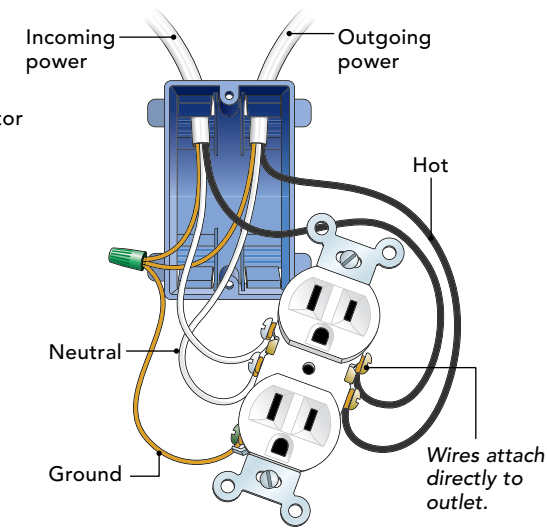
3. **Once you've assessed the setup** of the outlet, remove the wires from the terminal screws (or backstabs, if they're being used; see p. 67) and attach the new outlet in the same way. In a typical nonswitched receptacle, the green (or bare) ground wire goes to the green grounding screw; the neutral (white) wire(s) goes to the silver terminal(s); and the hot (black) wire(s) goes to the gold terminal(s).

4. **Secure the new outlet** and replace the cover plate.

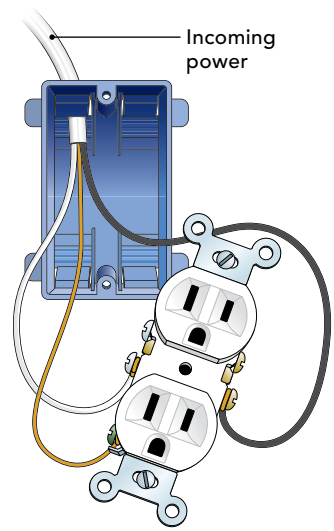
5. **Re-energize the circuit,** and check your work.



Splicing wires with pigtails *(short wires) to the outlet ensures continuous current downstream even if the outlet fails.*



Attaching hot and neutral wires *directly to the outlet's terminals is quicker and results in a less crowded box, but if the outlet fails, it can interrupt power downstream.*



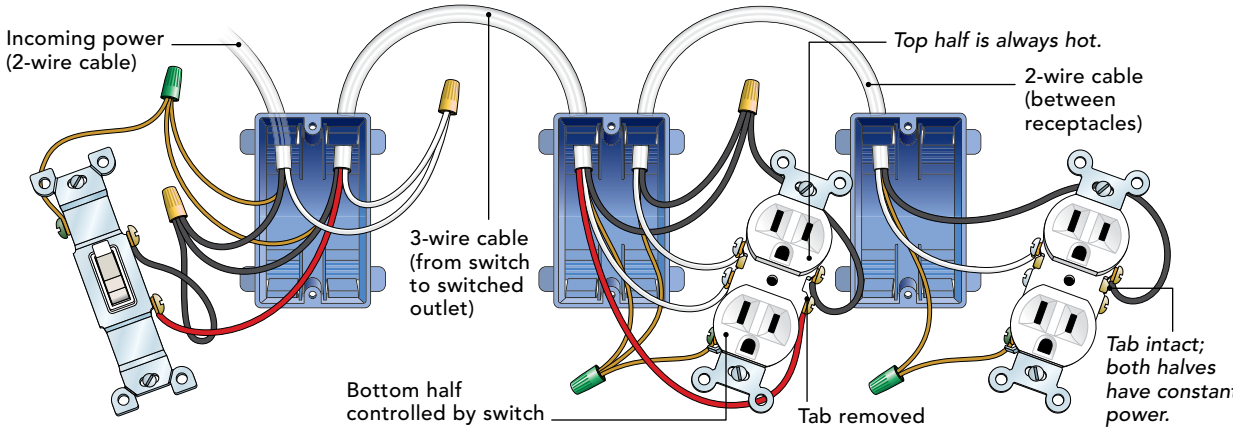
At the end of a circuit, *there is only one cable coming into the box, and all wires are connected directly to the outlet (no pigtails).*

Swap switched outlets

Switched outlets are just that— outlets controlled by a switch so that you can plug in a lamp and use a switch to turn it on and off. Most homes have at least a few switched outlets for code reasons.

Most switched outlets have a constant power source on one half of the outlet and a switched power source on the other. The easiest way to tell is if you have two different-color hot wires attached to the same outlet, and the little metal tab between the hot (gold) screws has been removed, enabling each outlet to operate independently. The drawing below shows one arrangement in which the switch controls only the bottom half of the split-tab outlet. The top half of the split-tab outlet and the next outlet in the circuit have constant power.

When replacing a switched outlet, you need to remove the tab between the hot terminals on the new outlet so that they can operate independently. Be sure to attach the hot wires as they were on the old device so that the same half remains switched.



REPLACE A SINGLE-POLE SWITCH

The next time you're at the hardware store grumbling about having to replace an unresponsive light switch, think about this: How much quality do you expect from a piece of equipment that costs less than a buck? The fact is that switches fail for lots of reasons besides product quality, including poor connections by the electrician, expansion and contraction of metal parts over time, and rough handling.

A single-pole switch is simply a switch that works alone to turn a fixture on and off. It is generally wired in one of two ways: one in which power comes to the switch first; and another, called a switch loop, in which power comes into the fixture and then is routed to the switch. Although the wires might look a bit different, they hook up to the switch the same way.

If you open a switch box and see only one cable coming in, it's probably a switch loop. Because there is only one cable in a switch loop, the white "neutral" functions as a "hot" to complete the circuit. To designate this, the white wire must be marked with black tape or marker. This marked wire is attached to one of the screw terminals just as a black "hot" would be (drawing below right).

HOW-TO

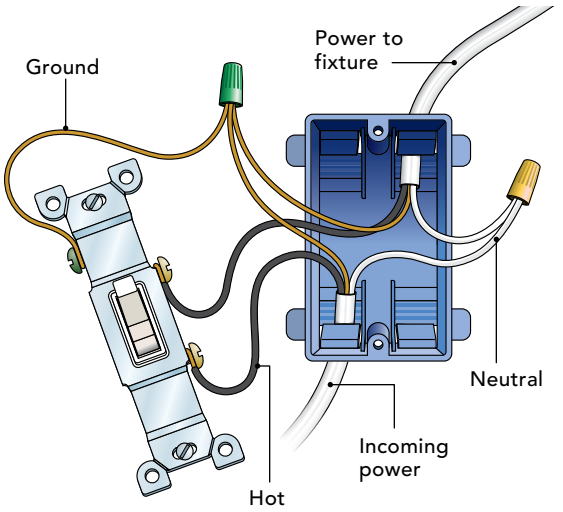
1. **Turn off the breaker** or pull the fuse supplying power to the box containing the switch. If the box contains multiple switches, be aware that each switch may be on a different circuit, and make sure everything is off by checking the operation of each switch and using a testing device.

2. **Remove the cover plate** with a 3/16-in. flat-blade screwdriver.

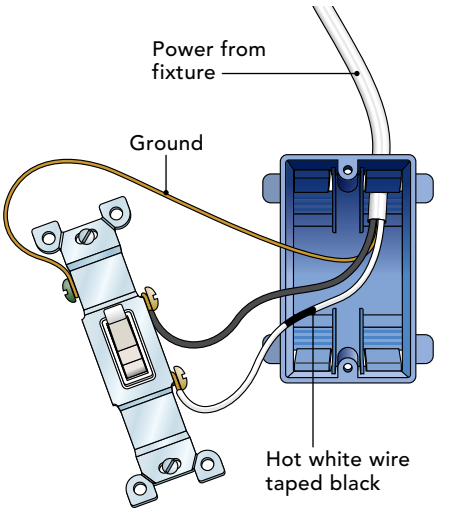
3. **Unscrew the switch from the box** and pull it out to access the terminal screws. The neutrals will be connected together in the back of the box; leave them alone. Disconnect the two hot leads from the switch's terminals (usually on the right side). Bare or green ground wires coming into the box will also connect to the box (if it is metal) and/or the switch itself. If the ground wire is attached to the switch, disconnect it.

4. **Make sure the new switch is oriented correctly** (the printed word "OFF" should be on top of the switch) before attaching the wires. Attach the ground wire to the green terminal and the black wires to the hot terminals. (The switch will operate regardless of which hot wire goes to which hot terminal, but I always route the incoming power wire to the bottom and the outgoing power to the top.)

5. **Replace the cover plate** and restore power to the circuit. Test the switch for proper operation.



Typical single-pole switch



Switch loop

A hot conductor must be paired with a neutral conductor (wire) to make a complete circuit. Neutral conductors are generally white or gray and constitute the "out" portion of the circle. If you look at an unplugged lamp, you can trace the path of electricity from the small end of the plug (hot/in), through the switch, through the bulb, and back to the large end of the plug (neutral/out). What this means is that every circuit in your house is really just a circle of energy.

Most residential electrical systems installed in the past 50 years also include a grounding conductor or ground wire. This additional wire helps to safeguard against electric shock or fire in the event of an electrical fault (any unintended discharge of energy, as when a loose wire contacts metal) by channeling that excess energy back to the ground and/or panel, where it should trip the breaker or blow the fuse. Grounding wires are generally bare or sheathed in green insulation and are not intended to carry electricity unless there is a malfunction. Never use a grounding wire in your home as a hot or neutral conductor because this incorrect usage presents a serious shock hazard. For more on grounding, see "Common problems," p. 66.

Safety first—and last

Now that I've covered the basics of how the system works, let's talk safety. I joked earlier about people's fears of electrical work, but in

REPLACE A THREE-WAY SWITCH

Whereas a single-pole switch is one switch that controls one fixture, a three-way switch is used when two switches control the same fixture. It may seem counterintuitive to call them "three-way" because they work in pairs. The name refers to their operation, so don't let it confuse you. The wiring will do that.

One reason three-way switches confuse people is because they are wired differently depending on the relative position of the fixture(s) and the switches. But there are some common denominators. Three-way switches have three terminal screws: Two are typically brass-colored, and one is usually black or dark and labeled "common." The coloring and labeling are important because the wiring must be connected in a specific way for the switches to operate properly. The common on one switch is the "in" side of the setup from the power source, and the common on the other switch is the "out" to power the light. Two other wires, called travelers, run between the switches. Power on the travelers alternates depending on whether the switches they're connected to are off or on. If the sequence completes the circuit, the light is on. If not, it's off.

Below are three typical setups you'll find when replacing a three-way switch. All things considered, the key to a simple three-way switch (pun intended) is to distinguish correctly the hot (common) wire from the travelers and to route all three to the correct terminals. The best way to do this is to identify and mark the wires carefully before disconnecting the old switch.

HOW-TO

1. **Turn off power to all the boxes containing the switches.** Three-way switches can be tougher to replace than single-pole switches because there are at least two boxes involved, and you need to make sure the power is off to all the switches in each box. Verify everything is off by using a testing device.

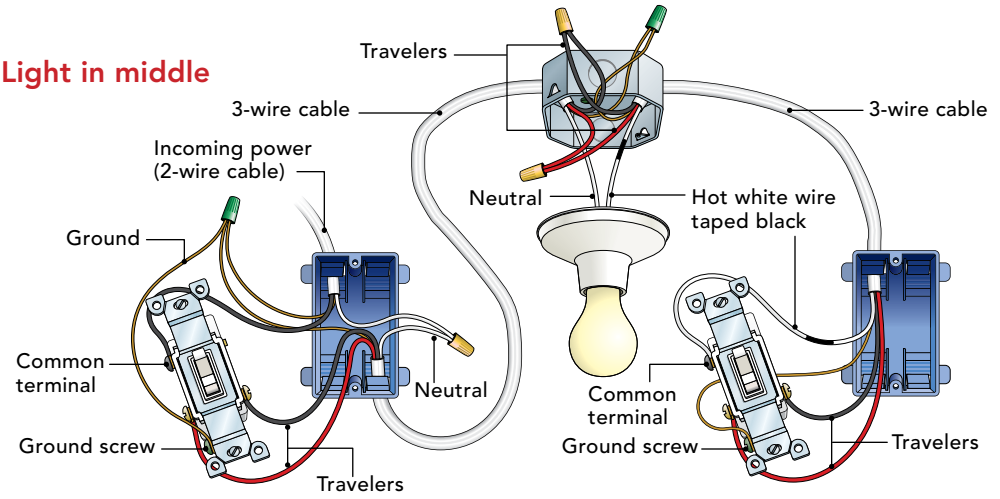
2. **Remove the cover plate**, typically with a 3⁄16-in. flat-blade screwdriver.

3. **Unscrew the switch from the box** and pull it out to access the terminal screws. Make a note of which wire is attached to the common terminal, and mark it. The common carries power either in to the switch or out to the fixture (drawings right). The travelers' connections don't really need to be distinguished from one another as long as you know which two wires they are. Taping the two travelers together and leaving the common loose is another way to keep from getting confused.

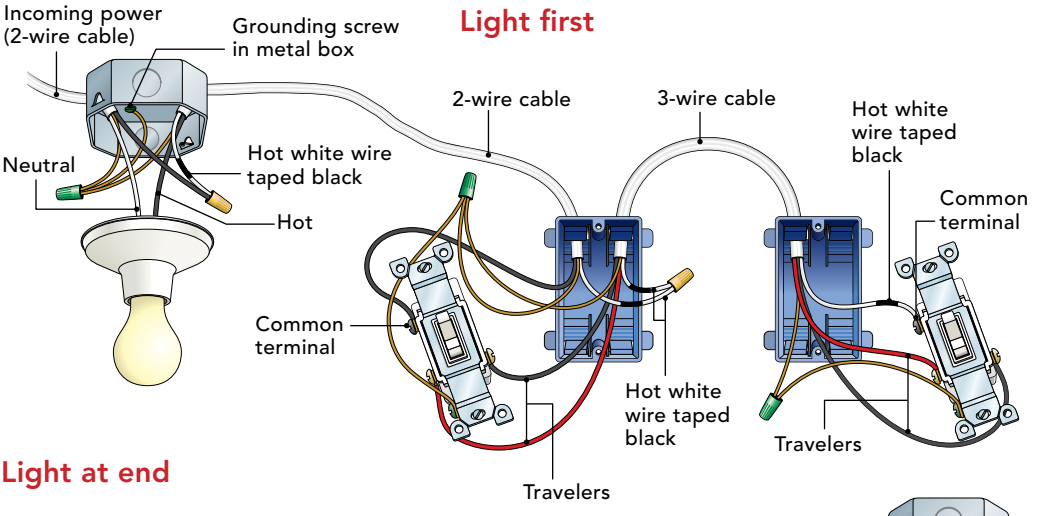
4. **Remove the wires from the screw terminals on the switch,** and replace it with the new switch. Reattach the ground wire to the green ground screw; make sure the traveler wires go to the traveler terminals, and the common wire goes to the common terminal. See the drawings at right for additional wiring details that apply to your specific situation.

5. **Replace the cover plate**, and restore power to the circuit. Test the switch for proper operation.

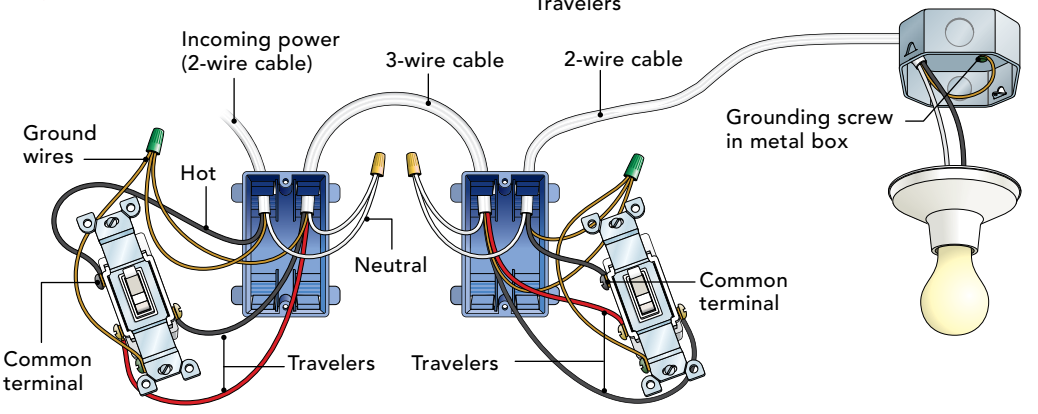
Light in middle



Light first



Light at end



REPLACE A LIGHT FIXTURE

Installing a new light fixture is about as straightforward a process as you will encounter when working on your electrical system. Perhaps because it's such a seemingly easy task, even the most electrically gun-shy folks I know will readily change out a light fixture. Perhaps that's also why, in the course of my remodeling work, most of the light fixtures I'm asked to change out are incorrectly installed (see "Common problems," below). Considering that most light fixtures are conductive (metal) and a part of the system that you will have routine contact with (changing bulbs, dusting, etc.), proper installation, including grounding, is a must. If yours is an older, ungrounded system, be sure to use an approved replacement or consult a professional.

HOW-TO

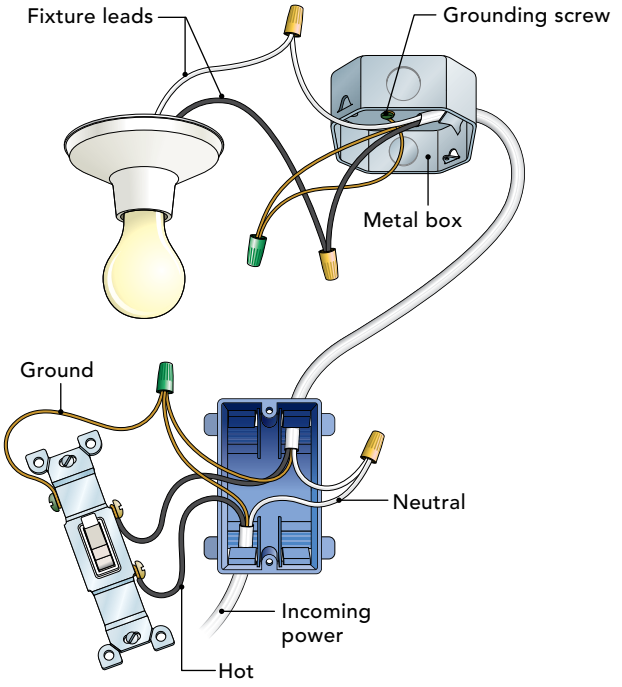
1. Always shut down power to the circuit the light is on instead of relying on the switch to determine that the power is off. With the numerous ways that wiring and switches can be configured, such as a switch loop, it's possible to have the switch in the off position and still have power in the fixture box.

2. Remove the old light, marking which wires attach to which colored leads on the old fixture. Install a fixture box if one does not exist. Your local home center carries a variety of "old work" box options (seemingly counterintuitive because it's a new fixture, but you're installing it into an existing or "old work" application).

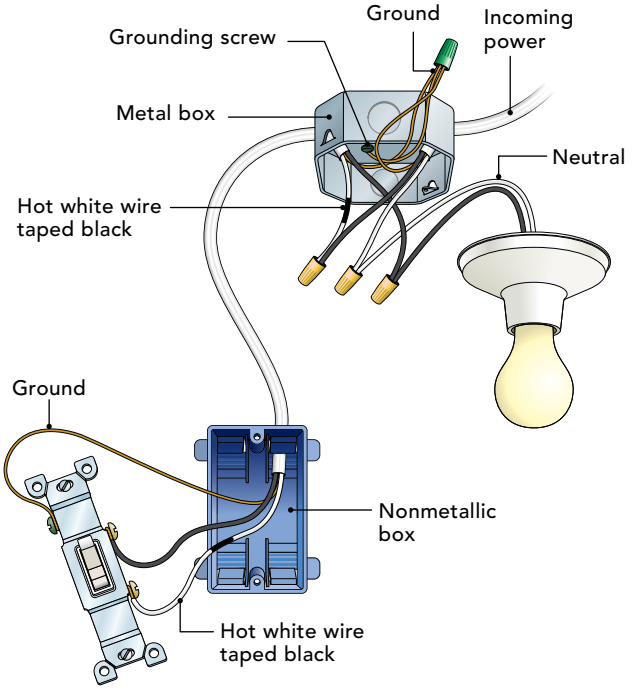
3. Install the mounting bracket for the new light fixture on the box, making sure it's securely fastened and the screw studs that support it are level so that it won't hang crookedly. After the bracket is installed, hold the fixture up to it and adjust the depth of the mounting-screw studs so that they allow for a tight fit of the fixture to the wall.

4. Connect the fixture's wire leads to the appropriate leads in the box. The fixture's ground lead (if it has one) should be attached to the grounding wire and/or to the green-colored grounding screw on the box (if it is a metal one). Then connect the neutral (white) fixture lead to the neutral cable wire, and connect the black fixture lead to the hot cable wire.

5. Attach the light securely, re-energize the circuit, and check your work.



Power from below



Power from above

Common problems with light fixtures

The biggest mistake I find with light fixtures is that they aren't installed in a box: I remove the light, and there's nothing behind it but a hole in the wall with a wire dangling out. All electrical connections within the confines of your home should be inside an electrical box approved for that use. Boxes not only provide a means to mount fixtures and wiring securely, but they also shield framing and other combustible materials in the event of a failed connection.

The second most common problem I uncover is that most light fixtures are not grounded. I can't count the number of light fixtures I've removed, only to have the ground wire come leaping out at me. I can only speculate that a lack of understanding is what makes this such a common problem.

So, to reiterate: Make sure that all fixtures are mounted in a box, and that the fixture's grounding wire, if it has one, is securely fastened to the circuit's ground wire and to the screw on the fixture box, if it is a metal one. If yours is an older, ungrounded system (without a ground wire), use a replacement approved for ungrounded systems, or consult an electrician about installing a ground wire or adding GFCI (ground-fault circuit interrupter) protection to the circuit.

Photo facing page: Rodney Diaz

Tips for trouble-free wiring

• MAKE A TIGHT CONNECTION

To ensure strong connections, twist wires together before screwing on the wire nut. This is particularly helpful when wiring fixtures with stranded wire leads; the physical differences between stranded and solid wiring can make these connections tricky. When making a connection between one stranded and one solid wire, I like to make at least one full wrap of the stranded wire around the solid wire, leaving the stranded wire a hair longer than the solid to be sure the strands engage the threads in the wire nut when it's twisted onto the pair. If I'm making a connection between a stranded wire and more than one solid wire, I use pliers to twist the solids together in a group; then I wrap the stranded wire around the group before capping with a wire nut, again leaving the stranded wire just a little long.

• MAKE A MAP

Before disconnecting wires in an electrical box, draw a quick sketch of what you see (noting wire color and connections) or snap a digital photo. Taping and numbering wires also help to keep things straight.

• WRAP IT RIGHT

Always wrap wire around screw terminals in a clockwise direction (the same direction they will be tightened). This prevents the wire from backing away from the screw as it's secured.

• BE CERTAIN ABOUT THE CIRCUIT

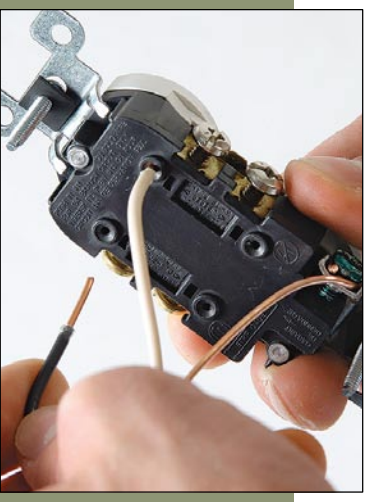
Tracking down the breaker or fuse that supplies power for a given circuit can be tricky. If you're replacing a switch, leave the light on and flip the breakers until the light goes out (you may need a helper to watch for you). It's a fast, easy way to determine which circuit controls that light. If you're working on an outlet, plugging in a lamp or vacuum cleaner provides you with a visual or audible indicator.

• BUY THE RIGHT DEVICE

New outlets and switches are required to be marked permanently with amperage and voltage ratings so that you know what you're getting. Household switches and receptacles typically operate on 120v current; most lighting circuits are 15- or 20-amp capacity circuits (you'll see the amps on the breaker or fuse). In most cases, the National Electrical Code allows for 120v/15-amp switches and receptacles on residential circuits rated up to 20 amps, so you really don't need more than basic 15-amp toggle switches and receptacles to be up to code. Some stores sell "heavy-duty" 20-amp devices for more money, but you probably don't need them unless you're replacing a 20-amp rated device or you like spending extra money.

• AVOID "BACKSTABS"

Push-wire slots or "backstabs" are holes in the back of a switch that allow you to push a wire into an anti-reverse terminal, making a connection similar to a Chinese finger cuff. I'm not a big fan of backstabs. I've repaired numerous problems resulting from them, so if possible, I move the wires from the backstabs to the screw terminals. If you are replacing an electrical device that has more than two conductors wired to it, you might still be able to avoid the backstabs by using pigtails or by purchasing a special screw-type backwire terminal. If you must use the backstabs, be aware that most of them accept only 14-ga. wire, so don't try to force 12-ga. wire into the hole.



reality, a little fear is a great thing. My fear of electricity helps me to maintain a healthy respect for the systems I work on, and your fear will help to keep you safe by alerting you to potential hazards.

The number-one safety rule I stress with my coworkers is something my high-school driving instructor once said: "If you don't know, don't go." Know your limitations. Unless you know that what you're doing is completely safe, don't do it. That means turning off the power when you're working on a circuit. It's not worth the risk of getting shocked or electrocuted, even if you have to shut down the whole house to be sure the wires you're handling are off.

I always shudder when I hear people say, "It's OK—it's only 120 volts" when referring to the possibility of electric shock. Let me be perfectly clear: 120v household current can and will kill you if you don't protect yourself. The black box on p. 62 outlines the safe work procedure I use. I advise you to use it, too.

Another crucial safety rule is to follow any and all directions provided with the devices or equipment you're working on. Even the most basic electrical devices come with directions, so take the time to read through them before you start, and again after you're done to make sure you didn't miss anything. When I come across a problem in someone else's wiring, 99% of the time it's because someone didn't follow simple directions. □

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Illustrations for this article were adapted from **Wiring Complete (Revised Edition)** by Michael Litchfield and Michael McAlister (The Taunton Press, 2008; www.taunton.com/wiringcomplete).